OCNMS Advisory Council
Climate Change Working Group Report for Sentinel Site Nomination

A strategy of the Olympic Coast National Marine Sanctuary (OCNMS or Sanctuary) Management Plan is to propose to National Oceanic Atmospheric Administration (NOAA) leadership that the Sanctuary be identified as a sentinel site for climate change research and monitoring. The following paragraphs give further justification as to why the Sanctuary should be considered a sentinel site for both ocean acidification and sea level rise.

Olympic Coast National Marine Sanctuary, situated along the outer coast of Washington State, acts as the environmental guardian for the Strait of Juan de Fuca, the Salish Sea, and the Strait of Georgia. The Sanctuary consists of 2,408 square nautical miles of marine waters and extends 20 to 50 miles offshore. Within sanctuary boundaries there are three deep sea canyons, including The Juan de Fuca Canyon, which functions as an underwater marine river funneling nutrient-rich, deep-ocean water into the estuary, feeding the circulation of the system (Alford and MacCready 2014). This canyon is approximately 6 kilometers wide and reaches 500 meters below the ocean's surface at its deepest point. Understanding the ocean water that flows toward the inland system is important because annual coastal upwelling has a significant influence on nutrient, oxygen and acidity levels within the Salish Sea. This situation contributes to both the region's rich productivity and to the exacerbation of problems like ocean acidification.

Ocean acidification (OA) and climate change share a common cause: increased input of carbon dioxide into the atmosphere. Although related, these two are distinct; ocean acidification refers to the lowering of the ocean's pH, whereas climate change refers to changing conditions in the Earth's atmosphere such as rising global temperatures and changes to weather patterns. Given that OCNMS borders the northern half of Washington's coast and lies at the mouth of the Strait of Juan de Fuca, it makes it an ideal candidate to be designated a sentinel site. This is true for climate change factors like seawater temperature and salinity, as well as ocean acidification factors, such as pH and carbon variables. The location is optimal because changes can be detected at the coast, prior to entering the Strait.

Significant research has already started in OCNMS relative to water conditions and ocean acidification. This historical information, in combination with data collected from OCNMS as a sustained sentinel site, would be a powerful source of data on ocean conditions. OCNMS has been conducting seasonal coastal monitoring of oceanographic conditions since 2000 providing data on temperature, salinity, and oxygen. NOAA scientists and partners use these variables to estimate pH and other ocean acidification variables. Through the Northwest Association of Networked Ocean Observing Systems (NANOOS, part of U.S. IOOS), scientists from the University of Washington have maintained a moored buoy system and seaglider to monitor ocean conditions since 2010, including these variables and expanding to pH, carbon variables, and nutrients, as part of NOAA's Ocean Acidification Program. UW's Washington Ocean Acidification Center conducts monitoring efforts at 9 stations between OCNMS and Seattle through the Strait of Juan de Fuca, bi-annually measuring plankton and water chemistry. They also involve educators from the OCNMS region to increase outreach and communication of this issue.

Many of the biological resources in OCNMS are susceptible to effects from ocean acidification. These include calcifiers, such as shellfish and pteropods, as well as deep sea corals. Effects on higher trophic level organisms, such as larger fish and marine mammals, are only now being researched. The importance of a sentinel site inside OCNMS is that these species are protected from many other direct stressors, allowing assessment of effects from ocean conditions more accurately.

Long-term sea level change can produce a variety of influences on coastal ecosystems, and may alter the morphology of shorelines, impact shallow sub-tidal and intertidal biological communities, and alter patterns of sediment supply from rivers to the coastal environment. Olympic Coast National Marine Sanctuary is now, and will continue to be, influenced by sea level rise (SLR), and offers a number of interesting opportunities to better understand how sea level rise interacts with temperate coastal ecosystems. There are three specific ways in which OCNMS provides unique opportunities to study SLR:

1) SLR rates are projected to be positive in the coming decades, but reduced relative to global rates in the Pacific Northwest (Figure 1). This discrepancy in the regional and global SLR projections provides an opportunity to compare the impacts of varying rates of sea level rise within the sentinel site system (i.e. at different sanctuaries).

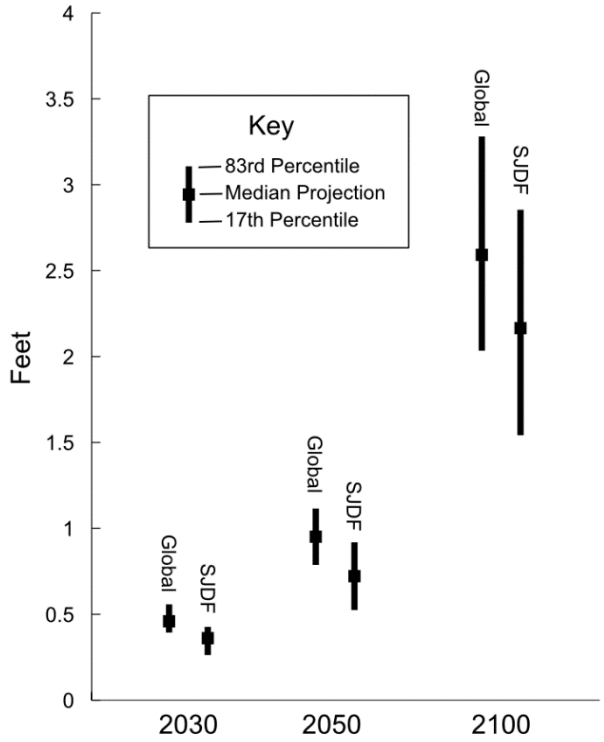

Figure 1. A comparison of the most likely ranges of global sea level rise and the projections for the Strait of Juan de Fuca (SJDF), derived from Kopp and others (2014) for 2030, 2050 and 2100. Figure: NOPRCD, *in prep*.

2) Relative rates will vary across the alongshore extent of shoreline within OCNMS. Rates of relative sea level rise vary considerably across the shoreline of OCNMS due primarily to variable rates of vertical land movement. The northern shoreline of the OCNMS

appears to be uplifting at rates of approximately 12 inches/century, while parts of the southern shoreline of OCNMS may be subsiding at rates of up to approximately 4 inches/century. These variable rates of vertical land movement create discrepancies in rates of relative sea level rise across the extent of the shoreline within OCNMS, which provide a very unique opportunity to study varying SLR influences on physical and ecological systems within a single sanctuary unit.

3) The shorelines of OCNMS are complex, of characterized by mixed grain size beaches, large woody-debris on the upper intertidal (Figure 2), and a crenulated planform. The response of these complex shoreline types to long-term sea level rise, storms and short-term sea level variability (associated with, for example, ENSO events) is generally poorly studied, and a focus on the response of shorelines within OCNMS could inform shoreline management. Additionally, much of the shoreline of OCNMS is undeveloped, effectively removing a confounding factor in terms of understanding the response of shorelines to oceanographic influences (due, for example, to wide scale armoring along heavily developed shorelines).

Figure 2. Students from Forks High School collect beach morphology data amongst the large logs in the upper intertidal zone near Kalaloch Lodge in the Olympic Coast National Marine Sanctuary. Image: Ian Miller

Overall, OCNMS is an excellent candidate for Sentinel Site status given the following reasons:

- its location as a gateway to the Salish Sea, allowing for detection of ocean acidification before entering an area of significantly valuable shellfish aquaculture industry;
- its undeveloped and rugged nature, minimizing other potentially synergistic attributes associated with development;
- its large network of supporting organizations, including academia and research institutes, tribal, local and state government management, non-governmental organizations, Marine Resource Committees and more;
- the availability of long-term oceanographic monitoring data and its importance to regional scientific databases;

- the susceptibility of natural resources to ocean acidification, from organisms at the base of the food chain (e.g. pteropods) to deep sea corals, and the potentially large impact to other marine life up the food chain;
- its unique position to study sea level rise and the regional variability
- its ability to serve as a pilot site, providing a framework that could be utilized by other national sites.

The Climate Change Working Group recommends proposing to National Oceanic and Atmospheric Administration (NOAA) leadership that OCNMS be identified as a sentinel site for both ocean acidification and sea level rise, both strong opportunities for climate change research and monitoring for the Pacific Northwest region.

Literature cited:

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